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Theoretical predictions for extraction of G_E^n from semi-inclusive electron scattering on polarized ${}^3\text{He}$ based on various nucleon-nucleon interactions

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The process ${}^3\text{He}(\vec{e}, e' n)$ is theoretically analyzed with the aim to search for sensitivity to the electric form factor of the neutron, G_E^n . Faddeev calculations based on five high precision nucleon-nucleon force models are employed, and stability versus exchange of the nucleon-nucleon forces is demonstrated.

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In a recent paper [1] we investigated the sensitivity of the process ${}^3\text{He}(\vec{e}, e' n)$ to the extraction of the electric form factor of the neutron. That study was based on the AV18 [2] nucleon-nucleon (NN) force and related meson exchange currents (MEC's) and Faddeev calculations for ${}^3\text{He}$ are consistent with the final state continuum. We found that final state interaction (FSI) effects were quite important and an analysis without FSI cannot be recommended. Though we know from most of our experience that the theoretical results are quite stable under exchange of one of the high precision NN potentials by another one, we would like to supplement our previous paper [1] by explicitly demonstrating the independence of the NN interaction for that specific process. We refer to Ref. [1] for all information about the formalism and the definitions of the asymmetries A_\perp and A_\parallel . Since in contrast to AV18 there are no consistent MEC's worked out for the other four high precision NN potentials, CD Bonn [3], Nijmegen 93, and Nijmegen I and II [4], we show only the asymmetries evaluated with those NN potentials based on the standard nonrelativistic single-nucleon current operator.

The important ratio A_\perp/A_\parallel for the extraction of G_E^n is displayed in Fig. 1 for the same q^2 values as in Ref. [1]. This figure corresponds to Fig. 8 of Ref. [1]. It shows the five predictions (including AV18) for a fixed choice of G_E^n as used in Ref. [1]. In order to provide the necessary information on the sensitivity with respect to G_E^n , we include also three additional curves, where G_E^n is multiplied by 0.75, 1.25, and 1, respectively, and this for the choice of AV18 + MEC. These additional three curves are the same as in Fig. 8 of Ref. [1]. We see in all cases a rather narrow spread of the five NN force predictions that document the expected stability of the results under exchange of one NN force by another one. However, we had to reduce somewhat the energy range near the upper end of the neutron energies in order to keep that spread small. Especially for the higher q^2 values, the spread increases quite a bit for the lower neutron energies (not shown). Experimentally it should be possible to

concentrate on that restricted upper energy range, where the cross section is anyhow largest.

Now the narrow spread is meant in relation to the variation of the predictions by changing G_E^n by $\pm 25\%$. From the three added curves we see that the shifts caused by the changes of G_E^n is by far larger than the spread induced by varying the NN forces. For example, at $q^2 = 0.45 \text{ (GeV/c)}^2$ and $E_n = 260 \text{ MeV}$, the spread due to different NN potentials is about 13%, whereas the shifts caused by the G_E^n variations reach 70%. We did not repeat the calculations by varying G_E^n for the NN force predictions with a single nucleon current alone, since one can safely expect that corresponding shifts would result, as for AV18 + MEC. Figure 1 shows that the sensitivity to a G_E^n extraction would not suffer from a theoretical uncertainty induced by the choice of the NN force. However, one also sees that MEC effects can only be neglected near the very upper end of that neutron energy spectrum. They are quite significant for $q^2 = 0.05\text{--}0.2 \text{ (GeV/c)}^2$. The filled square is the result for the scattering on a free neutron at rest. This is treated fully relativistically and will be referred to as the pure neutron result. Clearly, an analysis of data with such an oversimplified picture would be meaningless.

For the sake of completeness we also display A_\parallel and A_\perp separately in Figs. 2 and 3 (corresponding to Figs. 5 and 6 of Ref. [1]), now again, as in Fig. 1, restricted to that upper E_n energy range. The spread among all curves for A_\parallel is quite small and MEC effects for AV18 are also minor. The filled square is the pure neutron result. For A_\perp , which carries the dependence on G_E^n , we see again only small spreads. MEC effects are quite noticeable only for $q^2 = 0.1\text{--}0.2 \text{ (GeV/c)}^2$. Clearly FSI is mandatory: the pure neutron result, which is reached by antisymmetrized plane wave approximation (PWIAS) calculations [1] is far off. For the highest E_n values A_\parallel is very stable under exchange of the NN forces (effects below 1%). This observable is also insensitive to the G_E^n variations (changes are below 2%). That is why the ratio A_\perp/A_\parallel reflects the sensitivity of A_\perp to both effects.

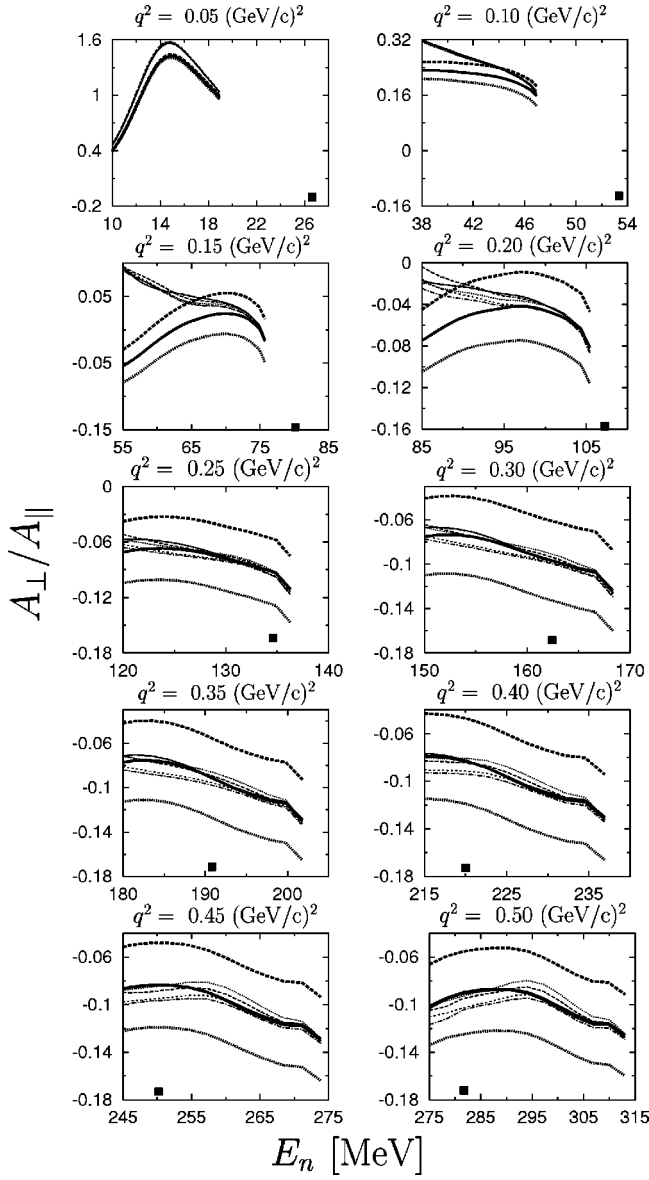


FIG. 1. The ratio A_{\perp}/A_{\parallel} as a function of the neutron energy E_n for different q^2 values. The thin lines correspond to full results (including FSI) without MEC's: CD Bonn (dash-dotted), Nijmegen 93 (dotted), Nijmegen I (short dashed), Nijmegen II (long dashed), and AV18 (solid). The thick lines are the full AV18 results including MEC's: with $1.0G_E^n$ (solid), with $0.75G_E^n$ (dashed), and with $1.25G_E^n$ (dotted). The filled square is the pure neutron result.

Summarizing, we conclude that theoretical uncertainties arising from replacing one of the modern high precision NN potentials by another one in the ratio A_{\perp}/A_{\parallel} are much smaller than the changes sought due to G_E^n variations. MEC effects, as evaluated in conjunction with AV18, decrease strongly at the upper end of the neutron spectra. Measurements concentrated to the upper end of the neutron energies

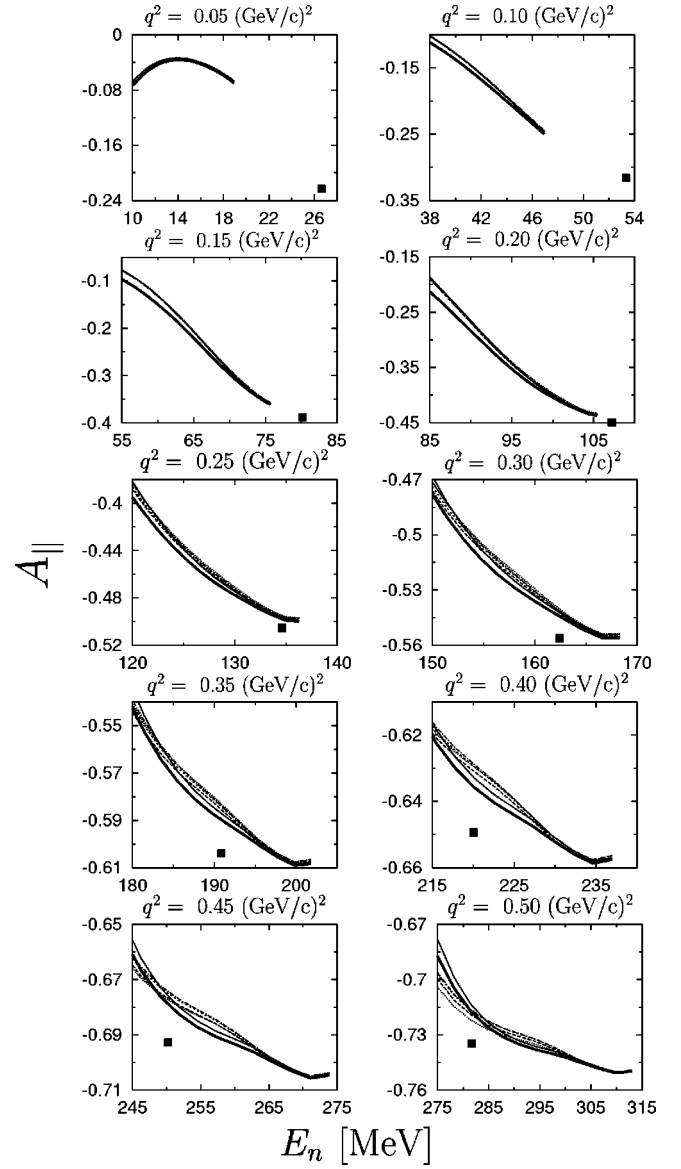


FIG. 2. A_{\parallel} as a function of the neutron energy E_n for different q^2 values. The thin lines and the symbol as in Fig. 1. The solid thick line is the full AV18 result including MEC's.

would be ideal and could provide important information on G_E^n .

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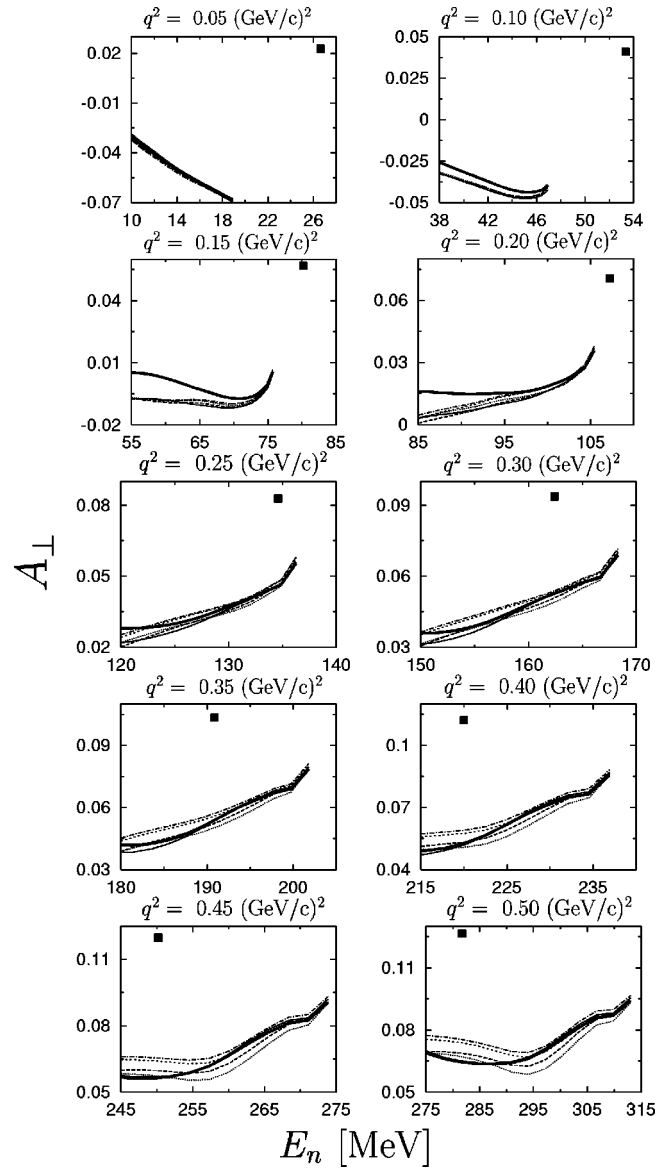


FIG. 3. A_L as a function of the neutron energy E_n for different q^2 values. Curves and the symbols are as in Fig. 2.

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